FORMPTO-1390(Modified) (REV11-98) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: 112740-155

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR): 09/787960

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/DE99/02737	01 September 1999	22 September 1998

TITLE OF INVENTION

METHOD AND APPARATUS FOR ESTIMATING THE TRANSMISSION QUALITY OF A DIGITAL COMMUNICATION SIGNAL

APPLICANT(S) FOR DO/EO/US

Thomas Hindelang

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ A copy of the International Search Report (PCT/ISA/210).
8. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☒ Certificate of Mailing by Express Mail
20. ☒ Other items or information:

Submission of Drawings - Figs. 1-6 on four sheets

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
09/787960	PCT/DE99/02737	112740-155

21. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :		CALCULATIONS	PTO USE ONLY
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO and International Search Report not prepared by the EPO or JPO	$1,000.00		
☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but Internation Search Report prepared by the EPO or JPO	$860.00		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO	$710.00		
☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4)	$690.00		
☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4)	$100.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =		$860.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).		$0.00	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	24 - 20 =	4	x $18.00	$72.00	
Independent claims	4 - 3 =	1	x $80.00	$80.00	
Multiple Dependent Claims **(check if applicable)**.			☐	$0.00	
TOTAL OF ABOVE CALCULATIONS			=	$1,012.00	
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) **(check if applicable)**.			☐	$0.00	
SUBTOTAL			=	$1,012.00	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)).			+	$0.00	
TOTAL NATIONAL FEE			=	$1,012.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).**			☐	$0.00	
TOTAL FEES ENCLOSED			=	$1,012.00	
				Amount to be: refunded	$
				charged	$

☒ A check in the amount of **$1,012.00** to cover the above fees is enclosed.

☐ Please charge my Deposit Account No. in the amount of to cover the above fees.
A duplicate copy of this sheet is enclosed.

☒ The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **02-1818** A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

William E. Vaughan
Bell, Boyd & Lloyd LLC
P.O. Box 1135
Chicago, IL 60690-1135

SIGNATURE

William E. Vaughan
NAME

39,056
REGISTRATION NUMBER

March 22, 2001
DATE

BOX PCT

IN THE UNITED STATES ELECTED/DESIGNATED OFFICE
OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
UNDER THE PATENT COOPERATION TREATY-CHAPTER II

PRELIMINARY AMENDMENT

APPLICANT:	Thomas Hindelang	DOCKET NO: 112740-155
SERIAL NO:		GROUP ART UNIT:
		EXAMINER:
INTERNATIONAL APPLICATION NO:		PCT/DE99/02737
INTERNATIONAL FILING DATE:		01 September 1999
INVENTION:	METHOD AND APPARATUS FOR ESTIMATING THE TRANSMISSION QUALITY OF A DIGITAL COMMUNICATION SIGNAL	

Assistant Commissioner for Patents,
Washington, D.C. 20231

Sir:

Please amend the above-identified International Application before entry into the National stage before the U.S. Patent and Trademark Office under 35 U.S.C. §371 as follows:

In The Specification:

On page 1, cancel lines 1-4 and substitute the following therefor:

--S P E C I F I C A T I O N

TITLE

METHOD AND APPARATUS FOR ESTIMATING THE TRANSMISSION QUALITY OF A DIGITAL COMMUNICATION SIGNAL

BACKGROUND OF THE INVENTION

Field of the Invention--.

On page 1, line 5, insert --present-- before "invention".

On page 1, lines 5-6, cancel "a device" and substitute therefor --an apparatus--.

On page 1, line 7, cancel the "," after "signal".

On page 1, before line 11, insert the following left-hand justified heading:

--**Description of the Prior Art**--.

On page 1, line 11, cancel "device" and substitute therefor --apparatus--.

On page 1, line 11, insert a --,-- after "serves".

On page 1, line 12, insert a --,-- after "particular".

On page 1, line 31, cancel "plurality" and substitute therefor --number--.

On page 2, line 3, insert a --,-- after "i.e.".

On page 2, lines 4-5, insert a --,-- after "and" and before "therefore".

On page 2, line 5, insert a --,-- after "therefore".

On page 2, line 7, insert a --,-- after "is".

On page 2, line 7, insert a --,-- after "therefore".

On page 2, line 22, insert a --,-- after "correspond".

On page 2, line 22, insert a --,-- after "case".

On page 2, line 23, cancel "comprise" and substitute therefor --include--.

On page 2, line 24, cancel the "," and substitute therefor a --;--.

On page 2, line 24, insert a --,-- after "example".

On page 2, line 25, cancel "comprise" and substitute therefor --include--.

On page 2a, line 3, cancel the "," and substitute therefor a --;--.

On page 2a, line 3, insert a --,-- after "i.e.".

On page 3, line 25, insert --they-- before "do".

On page 3, line 27, cancel "should".

On page 3, line 27, insert --should-- after "therefore".

On page 3, before line 29, insert the following centered heading:

--**SUMMARY OF THE INVENTION**--.

On page 4, line 10, cancel the ",".

On page 4, line 18, cancel "comprises" and substitute therefor --includes--.

On page 5, cancel lines 16-18 and substitute the following therefor:

--Additional features and advantages of the present invention are described in, and will be apparent from, the following Detailed Description of the Preferred Embodiments and the Drawings.

DESCRIPTION OF THE DRAWINGS--.

On page 5, line 21, cancel "comprising" and substitute therefor --including--.

On page 5, line 26, insert --present-- before "invention".

On page 6, line 5, insert --present-- before "invention".

On page 6, before line 10, insert the following centered heading:

--**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**--.

On page 6, line 20, cancel "the figure" and substitute therefor --Figure 1--.

On page 6, line 30, cancel "comprises" and substitute therefor --includes--.

On page 6, line 31, cancel the "," after "bits" and substitute therefor a --;--

On page 8, line 30, cancel the "," and substitute therefor a --;--.

On page 8, line 30, isnert a --,-- after "i.e.".

On page 8, line 34, cnacel "by means of" and substitute therefor --via--.

On page 9, line 2, cancel "means of".

On page 9, line 10, cancel "plurality" and substitute therefor --number--.

On page 9, line 31, cancel "essentially".

On page 10, line 25, insert a --,-- after "is".

On page 10, line 25, insert a --,-- after "therefore".

On page 11, line 3, cancel the ",".

On page 11, line 5, cnacel "plurality" and substitute therefor --number--.

On page 11, line 12, cancel "therefore".

On page 11, line 20, cancel "this means" and substitute therefor --meaning--

On page 12, line 19, cancel "comprises" and substitute therefor --includes--

On page 12, line 22, cancel “comprises” and substitute therefor --includes--.

On page 13, line 8, cancel “plurality” and substitute therefor --number--.

On page 13, line 8, cancel “, which” and substitute therefor --. This--.

On page 13, line 30, insert a --,-- after “may”.

On page 13, line 30, insert a --,-- after “case”.

On page 13, line 31, cancel the “,” after “only” and substitute therefor a --;--.

On page 13, line 33, insert --therefore,-- after the “,”.

On page 13, line 34, cancel “can therefore”.

On page 13, line 35, insert --can-- before “change”.

On page 14, after line 8, insert the following paragraph:

--Indeed, although the present invention has been described with reference to specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the spirit and scope of the invention as set forth in the hereafter appended claims.--

On page 20 (last page), cancel lines 1-4 and substitute the following centered heading therefor:

--**<u>ABSTRACT OF THE DISCLOSURE</u>**--.

On page 20, lines 6-7, cancel “is indicated, in which” and substitute therefor --wherein--.

On page 20, line 10, cancel “(1)”.

On page 20, line 12, cancel “(3)”.

On page 20, line 12, cancel “comprises” and substitute therefor --includes--.

On page 20, line 12, cancel “(5)”.

On page 20, cancel line 17.

In the Claims:

On page 15, cancel line 1, and substitute the following left-hand justified heading therefor:

--**I Claim As My Invention:**--.

Please cancel claims 1-24, without prejudice, and substitute the following claims therefor:

25. A method for estimating a transmission quality of a digital communication signal, the method comprising the steps of:

transmitting a sequence of bits by a transmitter;

allocating bit values for the bits at a receiver; and

obtaining a measure for the transmission quality via low-pass filtering of the bit values of the transmitted sequence of bits.

26. A method for estimating a transmission quality of a digital communication signal as claimed in claim 25, wherein the bit values and the measure for the transmission quality are determined on a bit-by-bit basis and are combined into a uniform data word and the low-pass filtering is carried out via amounts of the uniform data words.

27. A method for estimating a transmission quality of a digital communication signal as claimed in claim 25, the method further comprising the step of:

averaging of probability values of a given fixed number n of transmitted bits, prior to the step of low-pass filtering, wherein the low-pass filtering is carried out via mean values obtained by the averaging.

28. A method for estimating a transmission quality of a digital communication signal as claimed in claim 27, the method further comprising the steps of:

selecting the n bits with lowest allocation correctness probability from a given second number N of bits; and

forming a mean probability value of the n bits.

29. A method for estimating a transmission quality of a digital communication signal as claimed in claim 28, wherein, for each possible mean probability value, a number of bits among of the number of bits of the N bits having the mean probability value is determined.

30. A method for estimating a transmission quality of a digital communication signal as claimed in claim 28, wherein $5n<N<20n$.

31. A method for estimating a transmisison quality of a digital communication signal as claimed in claim 28, wherein the N bits form an organization unit of the digital communication signal transmitted between the transmitter and the receiver.

32. A method for estimating a transmission quality of a digital communication signal as claimed in claim 28, wherein the low-pass filtering is carried out with incomplete suppression in a stop band.

33. A method for estimating a transmission quality of a digital communication signal as claimed in claim 28, the method further comprising the steps of:

comparing the measure for the transmission quality obtained via low-pass filtering with at least one threshold to obtain a comparison result; and

using the comparison result as a control signal for switchover between different transmission modes of the digital communication signal.

34. A method for estimating a transmission quality of a digital communication signal as claimed in claim 33, the method further comprising the steps of:

allocating two thresholds to two different transmission modes;

effecting switchover from a first of the two transmission modes to a second of the two transmission modes if a lower of the two thresholds is understepped; and

effecting switchover from the second of the two transmission modes to the first of the two transmission modes if a higher of the two thresholds is exceeded.

35. A method for estimating a transmission quality of a digital communication signal as claimed in claim 33, wherein the different transmisison modes have respectively different data rates, and the second number N is defined proportionally to the respective data rate for each transmission mode.

36. An apparatus for estimating a transmission quality of a digital communication signal, for connection to an output of an equalizer of a receiver for the digital communication signal, wherein the apparatus receives from the equalizer, for a sequence of bits transmitted by a transmitter, bit values allocated by the equalizer and a measure of reliability of the allocation of the transmitted bits, wherein the apparatus comprises a low-pass filter which, by smoothing rapid fluctuations in the reliability measure, supplies a signal representative of the transmission quality.

37. An apparatus for estimating a transmission quality of a digital communication signal as claimed in claim 36, further comprising:

a computing circuit for calculating a mean value of the reliability measure of a given number n of transmitted bits.

38. An apparatus for estimating a transmission quality of a digital communication signal as claimed in claim 37, wherein the computing circuit includes

a selecting portion for selecting the n bits with a lowest reliability measure from a set of N bits, where N >n.

39. An apparatus for estimating a transmission quality of a digital communication signal as claimed in claim 38, wherein the reliability measure is a digital value with a width of i bits, and the selecting portion includes 2^i memory spaces for storing numerical values of frequencies of occurrence of displayable probability values.

40. An apparatus for estimating a transmission quality of a digital communication signal as claimed in claim 39, wherein the N bits form an organization unit of the digital communicational signal transmitted between the transmitter and the receiver.

41. An apparatus for estimating a transmission quality of a digital communication signal as claimed in claim 36, wherein the low-pass filter has incomplete suppression in a stop band.

42. An apparatus for estimating a transmission quality of a digital communication signal as claimed in claim 36, wherein the low-pass filter is an equiripple FIR low-pass filter.

43. An apparatus for estimating a transmission quality of a digital communication signal as claimed in claim 36, further comprising:

a metric generator for receiving an output signal of the low-pass filter, the metric generator comparing the output signal with at least one threshold and supplying a further output signal which, depending on a result of the comparison, defines a transmission mode which is to be used.

44. An apparatus for estimating a transmission quality of a digital communication signal as claimed in claim 43, wherein the metric generator compares the output signal of the low-pass filter with two thresholds and the control signal switches from a first to a second condition if a lower of the two thresholds is understepped, and switches from the second to the first condition if a higher of the two thresholds is exceeded.

45. A mobile terminal for a mobile radio system, the mobile terminal comprising an apparatus for estimating a transmission quality of a digital communication signal, for connection to an output of an equalizer of a receiver for the digital communication signal, wherein the apparatus receives from the equalizer, for a sequence of bits transmitted by a transmitter, bit values allocated by the equalizer and a measure of reliability of the allocation of the transmitted bits, the apparatus including a low-pass filter which, by smoothing rapid fluctuations in the reliability measure of the transmitted sequence of bits, supplies a signal representative of the transmission quality, wherein the mobile terminal is set up to transmit a control signal, which is supplied by the apparatus and is representative of the transmission quality, to a base station.

46. A mobile terminal for a mobile radio system as claimed in claim 45, wherein the control signal transmitted to the base station is an output signal of a metric generator of the apparatus.

47. A base station for a mobile radio system, comprising:

an apparatus for estimating a transmission quality of a digital communication signal, for connection to an output of an equalizer of a receiver for the communication signal, wherein the apparatus receives from the equalizer, for a sequence of bits transmitted by a transmitter, bit values allocated by the equalizer and a measure of reliability of the allocation of the transmitted bits, the apparatus

including a low-pass filter which, by smoothing rapid fluctuations in the reliability measure of the transmitted sequence of bits, supplies a signal representative of the transmission quality; and

a control unit which defines a transmission mode used for transmission between the base station and allocated mobile terminals depending on a control signal representative of the transmission quality.

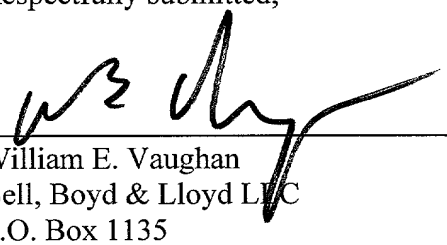
48. A base station for a mobile radio system as claimed in claim 47, wherein the control unit uses a control signal transmitted by the mobile terminal when defining the transmission mode.

REMARKS

The present amendment makes editorial changes and corrects typographical errors in the specification in order to conform the specification to the requirements of the United States Patent practice. No new matter is added thereby. Original claims 1-24 have been canceled in favor of new claims 25-48. Claims 25-48 have been presented solely because the revisions by bracketing and underlining which would have been necessary in claims 1-24 in order to present those claims in accordance with preferred United States Patent practice would have been too extensive, and thus would have been too burdensome. The amendment is intended for clarification purposes only and not for substantial reasons related to patentability pursuant to 35 U.S.C. §§101, 102, 103 or 112. Indeed, the cancellation of claims 1-24 does not constitute an intent on the part of the Applicant to surrender any of the subject matter of claims 1-24.

Early consideration on the merits is respectfully requested.

Respectfully submitted,



(Reg. No. 39,056)

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Description

Method and device for estimating the transmission quality of a digital communication signal

The invention relates to a method and a device for estimating the transmission quality of a digital communication signal, in which, for bits transmitted by a transmitter, a bit value is allocated at the receiver and a measure is determined for the reliability of the correctness of the allocation.

A method or device of this type serves in particular to estimate transmission quality in a mobile radio system and to adapt a transmission mode which is used to the available transmission quality.

A speech coder/decoder (codec) which is intended to carry out an adaptation of this type is currently being standardized following the standardization of the GSM Enhanced Fullrate (EFR) speech codec in the year 1996 under the name of Adaptive Multirate (AMR) speech codec as the next generation in ETSI SMG11. The main aims of the AMR codec are to achieve fixed-network quality for speech under different channel conditions and to ensure optimum distribution of channel capacity. The codec is intended to operate under good channel conditions and/or in highly utilized cells in the Halfrate (HR) channel. Under poor channel conditions, it is intended to change over dynamically with the aid of the GSM intra-cell handover to the Fullrate (FR) channel and vice versa. Within a channel mode (FR or HR), a plurality of code modes are available for different speech and channel coding rates, and are similarly intended to be varied according to channel quality (rate adaptation). Transmission with the respective highest possible quality is thus intended to be achieved, taking into account changing channel conditions.

A sufficiently accurate estimation of channel quality plays a decisive role in the selection of the modes used for transmission (i.e. on changeover between channel modes FR and HR and/or between code modes), and therefore also in the overall AMR concept. Ideally, the speech quality perceived by a user should serve as a criterion for the selection of a mode. It is therefore necessary to define a metric which enables objective measurement of such a priori subjective quality. Possibilities for derivation of such a channel quality metric are bursty RxLev, RxQual in the GSM system, DTX Activation, Frequency Hopping Activation, bit-by-bit or bursty channel state information (CSI) from the equalizer, Residual Error Rate of the channel decoder, Bad Frame Indicator (BFI), Error Concealment in the channel or speech decoder, etc.

The present invention is based on an estimation of transmission quality on the basis of channel state information (CSI), as supplied, for example, in the form of soft bits by an equalizer of a conventional mobile radio receiver. Soft bits of this type correspond in each case to one bit of the communication signal transmitted by radio and comprise a given number of bits, for example 8 or 16. The soft bit may comprise a signed integer with values between -2^{i-1} and $2^{i-1}-1$, i = for example 8 or 16, and provides a measure of the reliability with which a bit of the communication signal is identified in the equalizer. Thus, for example, a value -2^{i-1} of the soft bit designates the reliable identification of a "-1" bit of the communication signal, while the value $2^{i-1}-1$ designates the reliable identification of the "+1" value, the value -1 being logically assigned to ONE and +1 being logically assigned to ZERO. Intermediate values in each case correspond to variously reliable identifications. The sign (MSB) of the soft bit contains the decision of the equalizer as to whether a

transmitted bit of the communication signal was +1 or -1. The amount of the soft bit indicates how reliable this decision was, i.e.

it is a measure of the reliability that the allocation of the MSB to the transmitted bit is correct.

These soft bits are conventionally used in the receiver to restore the transmitted communication signal as faithfully as possible to the original. The reliability measures contained therein are not suitable for estimating the transmission quality of a channel. The reason for this is that the transmission quality of mobile radio channels is determined by fluctuations in transmission quality due to different causes. Thus, for example, short-term fading, i.e. rapid changes in reception power within a few milliseconds, are generally caused by reflection, refraction and interference in an otherwise unchanged spatial environment. Shadowing as a result of slow changes in the geographical environment, caused by the movement of individual mobile radio subscribers, produces long-term fading in which the mean reception power changes in time intervals of a few seconds. The effects of short-term fading on transmission quality can be reduced in a simple manner by temporal interleaving of data blocks. Short-term deteriorations in the reception signal have significant effects on the identification reliability of the equalizer, but, provided that they can be contained by interleaving, do not yet necessarily result in a deterioration in the transmitted speech quality and should therefore be ignored in estimating the latter.

A simple possibility for achieving the objective of simple and fast estimation of transmission quality is, according to the present invention, low-pass filtering of reliability values of a transmitted sequence of bits.

These reliability values are preferably derived from the soft bits by deriving the amount of the soft bit which is assumed to be a signed integer.

It is furthermore preferable for the low-pass filtering to be preceded by averaging of the reliability values of a given first member n of transmitted bits, in which the n bits with the lowest allocation reliability are selected from a given second number N of bits and the mean reliability value of these n bits is formed. The reason for this measure is that, even with poor transmission quality, the equalizer still frequently supplies or allocates a large number of bits with very high reliability, so that, with averaging of the reliability values of all transmitted bits, the mean value obtained would represent only a very insensitive measure of the transmission quality.

The ratio of the members n, N is preferably $5n<N<20n$, or preferably $10n \cong N$. A burst of a communication signal transmitted according to the AMR convention comprises N=114 bits. The n=10 most unreliable bits are selected from these and used for averaging.

The low-pass filtering is preferably carried out with incomplete suppression in the stop band above a small number of Hz. An equiripple FIR filter, for example, is suitable for this purpose. The incomplete suppression allows it to respond more quickly to abrupt long-term changes in transmission quality than it would in the case of filtering with complete suppression.

The low-pass filtered signal is preferably compared with at least one threshold in order to obtain a comparison result which is used as a control signal to switch over between different transmission modes of the communication signal. In order to prevent rapid switching backwards and forwards between transmission modes when the transmission quality fluctuates in a borderline area, it is appropriate to introduce a hysteresis in the switchover between different transmission modes.

To do this, two thresholds can be allocated to two different transmission modes in such a way that a switchover is effected from a first of the two transmission modes to the second if the lower of the two thresholds is understepped, and a switchover from the second to the first transmission mode is effected if the higher of the two thresholds is exceeded. If the different transmission modes have different data rates, it is furthermore preferable for the number N of bits from which the respective most unreliable soft bits are selected to be predefined for each transmission mode proportional to its data rate. This ensures that the speed of response to a change in transmission quality is the same for the different transmission modes, regardless of their data rate.

Further features and advantages of the invention are set out in the following description of embodiments with reference to the figures, in which:

Figure 1 shows a block diagram of a base station of a telecommunications system with mobile terminals, comprising a device for estimating transmission quality according to the present invention;

Figure 2 shows a block diagram of a mobile terminal which is equipped with a device according to the invention and which communicates with the base station from Figure 1;

Figure 3 shows a measured pattern of the long-term fading in the course of a communication signal;

Figure 4 shows the result of an estimation of the reception quality for the same communication signal with averaging over the ten bits with the lowest reliability within a burst;

Figure 5 shows the result with averaging over all bits of a burst;

Figure 6 shows the pulse response and frequency response of a low-pass filter of a device according to the invention; and

Figure 7 illustrates the conversion of an estimated value of the transmission quality of a communication signal into a control signal for switchover between different transmission types.

Figure 1 is a substantially schematic representation of a section of a base station for a telecommunications system which uses a device 1 for estimating the transmission quality of a digital communication signal. The base station receives the digital communication signal via an antenna 2. An equalizer 3 connected to the antenna 2 supplies a soft bit which has a width of, for example, 8 bits, for each bit received by the antenna.

The output signal of the equalizer is fed to processing circuits (not shown in the figure) in order to reconstruct the transmitted communication signal. The output of the equalizer 3 is furthermore connected to an input of a CSI generator 4 of the estimating device 1. The CSI generator 4 estimates the short-term fading of the transmission channel, determining the transmission quality of each individual burst of the communication signal. Depending on the transmission mode of the communication signal, the latter contains a different number of bursts for each speech frame. In full-rate transmission, a speech frame comprises four bits, in half-rate transmission, two bits.

The processing of each individual burst is carried out for an equalizer with an 8-bit resolution in accordance with the C program code set out below.

C program code

```
Word16 num_to_compute=10
Word16 sort [128];

/* Initialization */
for (n=0;n<128;n++)
sort [n] = 0

/* count bits with specific reliability */
for (n=0;n<114;n++)
sort  [        abs(burst)[n])        ] + +;

n=0; sum=0;
while (1)   {
if (sort) [n]==0    /* no bit with reliability n present */
n++;
else {
if(sort) [n]<num_to_compute )  [
sum += sort[n]*n;  /* determine number of bits still to be
calculated */
n++;
}
else {
sum += num_to_compute*n;
break;
}
}
}
```

The sign of each soft bit always corresponds to the presumed value of the received bit, and the amount is an integral value between 0 and 127, containing a measure of the reliability of the decision relating to the sign.

An amount of 0 represents a very unreliable decision and 127 represents a very reliable decision.

A temporary "sort" data field with a size of 128 is created for the $2^7=128$ possible different values of the reliability information and is initialized with 0. In a first loop, a measure of the probability that the sign of the soft bit corresponds to the relevant bit of the transmitted communication signal is derived, initially by forming the amount, for the individual soft bits "burst[n]", 0<n<114, and the number of bits within the burst with a specific reliability value is determined and stored according to this value in the "sort" field. Here, the field index represents the reliability and the field context represents the number of bits with this reliability which are present in the burst. Thus, for example, "sort[10]=12" means that there are 12 bits with a reliability of 10. In a second loop, the reliability values of the 10 least reliable bits are added together, starting with the index 0 with the lowest reliability. Division of the sum obtained by the number of bits added together provides a first mean value.

The CSI generator 4 furthermore performs a second averaging in which the aforementioned mean values over the 10 bits with the lowest reliability value of a burst for a number K of bursts are in each case added together and divided by K. The number K is equal to 2 for half-rate transmission and equal to 4 for full-rate transmission. It therefore corresponds to the number of bursts per frame, i.e. it is proportional to the data rate of the transmission mode. Due to the dependency of the number of bursts taken into account on the transmission mode, estimated transmission quality values are provided by means of the second averaging with a fixed repetition rate independent of the transmission rate.

The output signal of the CSI generator 4 obtained by means of this averaging is approximately proportional to the short-term fading of the mobile radio channel on which the communication signal is transmitted. The resulting substantial fluctuations in the output signal of the CSI generator 4 are suppressed with the aid of a low-pass filter 5. The reason for using the low-pass filter 5 instead of averaging over a substantial time interval is that simple averaging beyond a plurality of frames would not produce a satisfactory result, since short-term substantial interference would continue to result in a considerable decrease in the estimated transmission quality, which could indicate that a transmission mode changeover was necessary, even if the decrease lasts such a short time that it can be compensated by interleaving. Unweighted averaging therefore represents a poor low-pass filter. For this reason, the low-pass filter 5 is connected to the output of the CSA generator 4 in the estimating device 1 with the following specifications:

- Filter type: FIR equiripple low-pass filter (constant stop band)
- Filter order: 28
- Sampling rate: 50 Hz
- Passband: 0.2 Hz
- Stop band: 1.8 Hz at 20 db attenuation

Figure 6 shows in Part A the transmission function $h(t)$ of a filter of this type, and Part B shows the frequency response $20\log(|H(2\pi f)|$ in decibels as a function of the frequency f in Hz. Other possibilities for low-pass filtering are essentially also possible, for example Butterworth, Tschebyscheff, IIR filters, etc., or weighted averaging, the weight of a soft bit decreasing with increasing age.

Figure 3 shows an example of a measured pattern of the long-term fading of a real communication

signal over 2000 frames, corresponding to a time span of 40 seconds (transmission

rate 50 frames per second). The signal-to-noise ratio C/ (I+N) in decibels is plotted on the X-axis.

Figure 4 shows the estimation of the reception quality of the communication signal supplied by the low-pass filter 5 with the fading behavior shown in Figure 3. The numerical values of the output signal of the low-pass filter 5, which may be between 0 and 127 (for soft bits with an 8-bit width) are plotted on the X-axis. As can be seen, the times of occurrence of the signal quality extremes from Figure 3 and the estimation from Figure 4 correspond excellently at 700, 1070 and 1490. The amplitude of the deviations of the estimation from Figure 4 also corresponds closely to the pattern shown in Figure 3.

Figure 5 shows for comparison the result of an estimation in which all 114 soft bits of a burst have been taken into account, and not only the 10 with the lowest reliability value, as in the case of Figure 4. Although the position of the extremes still corresponds closely to that of the extremes in Figure 3, the amplitude of the deviations is reduced to around half. With 760 frames, the estimation shows a minimum to which no minimum of the measured fading curve from Figure 3 corresponds. The reliability of the estimation is therefore lower overall than in the case of Figure 4.

As can be seen, the pattern of the measurement curve from Figure 3 can be accurately reproduced through selection and averaging of the n=10 bits with the lowest reliability value from a burst of N=114 bits. It is obvious that, depending on the conditions of use, the quality of the equalizer 3 or other factors, a different value for the number n of the selected bits can produce a closer correspondence between the estimation and a measured quality pattern. It is assumed that, in the cases relevant in practice, a ratio of $5n<N<20n$ will be satisfied.

The output signal of the low-pass filter 5 is present at the output of a metric generator 6. This metric generator 6 is a further-developed comparator, which compares the filter output signal with a plurality of thresholds and, depending on the comparison result, generates a control signal with a width of 2 bits. Horizontal lines A, B, C corresponding to the thresholds are shown in Figure 7 over a curve which corresponds to the curve from Figure 3. If the output signal L_{filt} of the low-pass filter 5 is greater than the threshold B, i.e. the transmission quality is therefore very high, the control signal has the binary value 10. In the case of high channel quality where $B>L_{filt}>A$, it has the binary value 11, in the case of poor channel quality where $A>L_{filt}>C$, it has the value 01 and, in the case of very poor channel quality where $L_{filt}>10$, it has the value 00. As can be seen, only one bit of the control signal changes in each case when the filter output signal L_{filt} crosses one of the thresholds; this means that the control signal is Gray-coded.

The thresholds A, B, C can be freely selected and in each case specify the limits at which the transmission mode is to be switched over. They have the following meaning:

- Threshold A: Switchover from the transmission mode with the highest speech rate to a transmission mode with an average speech rate when the threshold is understepped,
- Threshold B: Switchover from the transmission mode with an average speech rate to the transmission mode with the highest speech rate when the threshold is exceeded; and,
- Threshold C: Switchover from the average speech rate to the transmission mode with the lowest speech rate and vice versa.

If a higher value is selected for the threshold B than for the threshold A, a hysteresis is

introduced for the switchover process, i.e. the channel quality must be higher for the switchover from the average to the highest rate

than for the switchover from the highest to the average rate. Continuous switchover between these two transmission modes is thereby prevented when the channel quality fluctuates in the area of the thresholds A, B.

The control signal is present on a first input of a control unit 7. The control unit 7 evaluates the control signal and effects the rate adaptation for the transmission from the mobile terminal to the base station (uplink). For this purpose, it transmits a required uplink rate (UL_REQ_Rate) inband, i.e. together with the speech bits, to the mobile terminal. The mobile terminal on the other hand transmits the transmitted uplink rate as UL_RATE and transmits the control signal to the base station.

Figure 2 shows a substantially schematic block diagram of the mobile terminal which can interwork with the base station from Figure 1. Like the base station, it comprises an equalizer 3 which, using communication signals received via an antenna 2, supplies soft bits to an estimation device 1 which, as with the device from Figure 1, comprises a CSI generator 4, a low-pass filter 5 and a metric generator 6. The control signal generated by the metric generator 6 is transmitted via an antenna 8 to the control unit 7 of the base station which, as indicated above, adapts the downlink transmission mode depending on the control signal supplied by the mobile terminal.

The control unit 7 evaluates the control signal received by the mobile terminal via the antenna 2 in the same way as the signal supplied to the base station by the metric generator 6.

The conversion of the signal L_{filt} into a 2-bit control signal is necessary because the control unit 7, in order to control the rate adaptation of the downlink from the base station to the mobile terminal, constantly requires information relating to the quality

of the downlink, which must be supplied to it by the mobile terminal. However, very few bits are available to transmit this information. Transmission of only the most significant bits of the filter output signal L_{filt} would therefore produce too rough a quantization. Transmission of a more finely quantized or complete filter output signal on the other hand would have to be divided over a plurality of frames, which would, however, result in a significant increase in the switchover delay. The 2-bit control signal of the metric generator 6 on the other hand can be transmitted in each speech frame to the base station so that the latter can redefine the transmission mode after each speech frame.

This evaluation of the control signal in the control unit 7 is carried out in the same manner for uplink and downlink transmission as follows: numerical values 3, 2, 1 and 0, which change uniformly with the transmission quality, are allocated to the control signal values dual 10, 11, 01 and 00. The current numerical value and the last seven numerical values (i.e. the results of the transmission quality estimation for the last eight frames) are added together and, depending on the sum, a transmission mode is selected which defines a speech transmission rate. This is used in the case of the downlink for transmission and, in the case of the uplink, is transmitted to the mobile terminal as a command to set an uplink rate.

Consecutive numerical values may in each case change by one step only, i.e., for example, a numerical value of 3 can be followed only by the numerical value 3 again or by 2. The transmission rate, which is defined in dependence thereon, can therefore also change by one step only between two frames. This can be exploited as a priori information in order to minimize

transmission errors and therefore high-interference speech module errors.

Instead of the decentralized decision described here in respect of the transmission modes to be used by the base station control unit for the uplink and downlink, a modification is also conceivable in which the mobile terminal independently decides on the transmission mode to be used for the uplink and/or downlink and transmits corresponding setting commands to the base station.

Claims

1. Method for estimating the transmission quality of a digital communication signal, in which, for bits transmitted by a transmitter, a bit value is allocated at the receiver and a measure is determined for the reliability of the allocation, characterized in that a measure for the transmission quality is obtained by means of low-pass filtering of the reliability values of a transmitted sequence of bits.

2. Method according to claim 1, characterized in that the value and the measure of its reliability are determined on a bit-by-bit basis and are combined into a uniform data word (soft bit) and the low-pass filtering is carried out via the amounts of the soft bits.

3. Method according to claim 1 or 2, characterized in that the low-pass filtering is preceded by averaging of the probability values of a given fixed number n of transmitted bits, and the low-pass filtering is carried out via the mean values obtained.

4. Method according to claim 3, characterized in that the n bits with the lowest allocation correctness probability are selected from a given second number N of bits and the mean probability value of these n bits is formed.

5. Method according to claim 4, characterized in that, for each possible probability value, the number of those bits among the N bits which have the value is determined.

6. Method according to claim 4 or 5, characterized in that $5n<N<20n$ and preferably $10n \cong N$.

7. Method according to claim 4, 5, or 6, characterized in that the N bits in each case form an organization unit of the communication signal transmitted between the transmitter and the receiver.

8. Method according to one of the previous claims, characterized in that the low-pass filtering is carried out with incomplete suppression in the stop band.

9. Method according to one of the previous claims, characterized in that the low-pass-filtered measure is compared with at least one threshold (A, B, C) in order to obtain a comparison result which is used as a control signal for switchover between different transmission modes of the communication signal.

10. Method according to claim 9, characterized in that two thresholds (A, B) are allocated to two different transmission modes in such a way that switchover is effected from a first of the two transmission modes to the second if the lower of the two thresholds (A) is understepped, and switchover is effected from the second to the first transmission mode if the higher (B) of the two thresholds is exceeded.

11. Method according to claim 9 or 10, and referred back to claim 4, characterized in that the different transmission modes have different data rates, and the second number N is defined proportionally to the data rate for each transmission mode.

12. Device for estimating the transmission quality of a digital communication signal, for connection to the output of an equalizer (3) of a receiver for the communication signal, wherein the device (1) receives from the equalizer (3), for bits transmitted by a transmitter, bit values

allocated by the equalizer (3) and a measure of the reliability of the allocation of the transmitted bits, characterized in that the device (1) comprises a low-pass filter (5) which, by smoothing rapid fluctuations in the reliability measure of a transmitted sequence of bits, supplies a signal representative of the transmission quality estimation.

13. Device according to claim 12, characterized in that it comprises a computing circuit (4) for calculating the mean value of the reliability measures of a given number n of transmitted bits.

14. Device according to claim 13, characterized in that the computing circuit (4) comprises means for selecting the n bits with the lowest reliability measure from a set of N bits (N>n).

15. Device according to claim 14, characterized in that the reliability measure is a digital value with a width of i bits, and that the means for selection (4) comprise 2^i memory spaces for storing numerical values of the frequencies of occurrence of the displayable probability values.

16. Device according to claim 15, characterized in that the N bits form an organization unit of the communication signal transmitted between a transmitter and the receiver.

17. Device according to one of claims 12 to 16, characterized in that the low-pass filter (5) has incomplete suppression in the stop band.

18. Device according to one of claims 12 to 17, characterized in that the low-pass filter (5) is an equiripple FIR low-pass filter.

19. Device according to one of claims 12 to 18, characterized by a metric generator (6) which receives the output signal of the low-pass filter (5), compares it with at least one threshold (A, B, C) and supplies an output signal which, depending on the result of the comparison, defines a transmission mode which is to be used.

20. Device according to claim 19, characterized in that the metric generator (6) compares the output signal of the low-pass filter (5) with two thresholds (A, B) and the control signal switches from a first to a second condition if the lower (A) of the two thresholds is understepped, and from the second to the first condition if the higher (B) of the two thresholds is exceeded.

21. Mobile terminal for a mobile radio system, and characterized in that it comprises a device (1) according to one of claims 12 to 20, and the terminal is set up in order to transmit a control signal, which is supplied by the device (1) and is representative of the transmission quality estimation, to a base station.

22. Terminal according to claim 21 and referred back to claim 19 or 20, characterized in that the control signal transmitted to the base station is the output signal of the metric generator (6).

23. Base station for a mobile radio system, characterized in that it comprises a device (1) according to one of claims 12 to 20 and a control unit (7) which defines the transmission mode used for transmission between the base station and the allocated mobile terminals depending on a control signal representative of the transmission quality estimation.

24. Base station according to claim 23, characterized in that the control unit (7) is set up to define the transmission mode used with the aid of a control signal transmitted by the mobile terminal.

Abstract

Method and device for estimating the transmission quality of a digital communication signal

A method for estimating the transmission quality of a digital communication signal is indicated, in which, for each bit transmitted by a transmitter, a measure is determined at the transmitter for the reliability of its correct identification is determined and subjected to low-pass filtering. A device (1) to carry out the method can be connected to an equalizer (3) and comprises a low-pass filter (5) which, by smoothing the probability measure, supplies a signal representative of the estimation of the transmission quality.

Figure 1

FIG 1

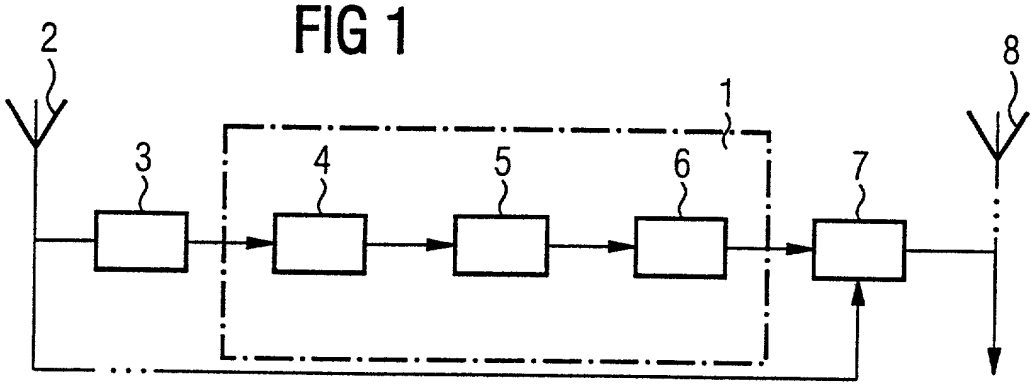


FIG 2

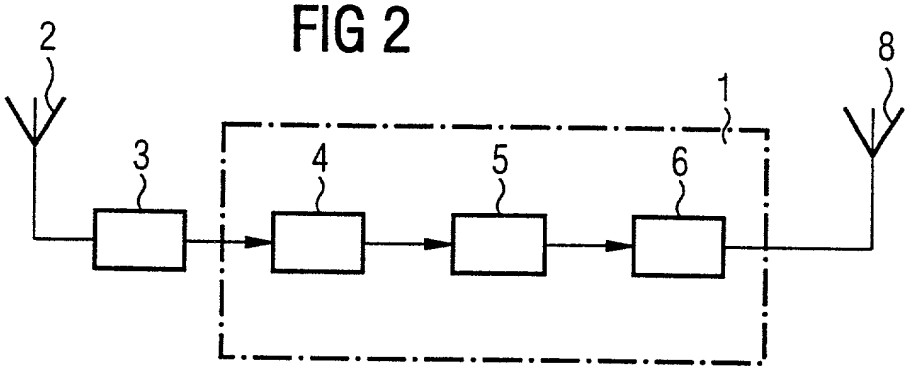


FIG 3

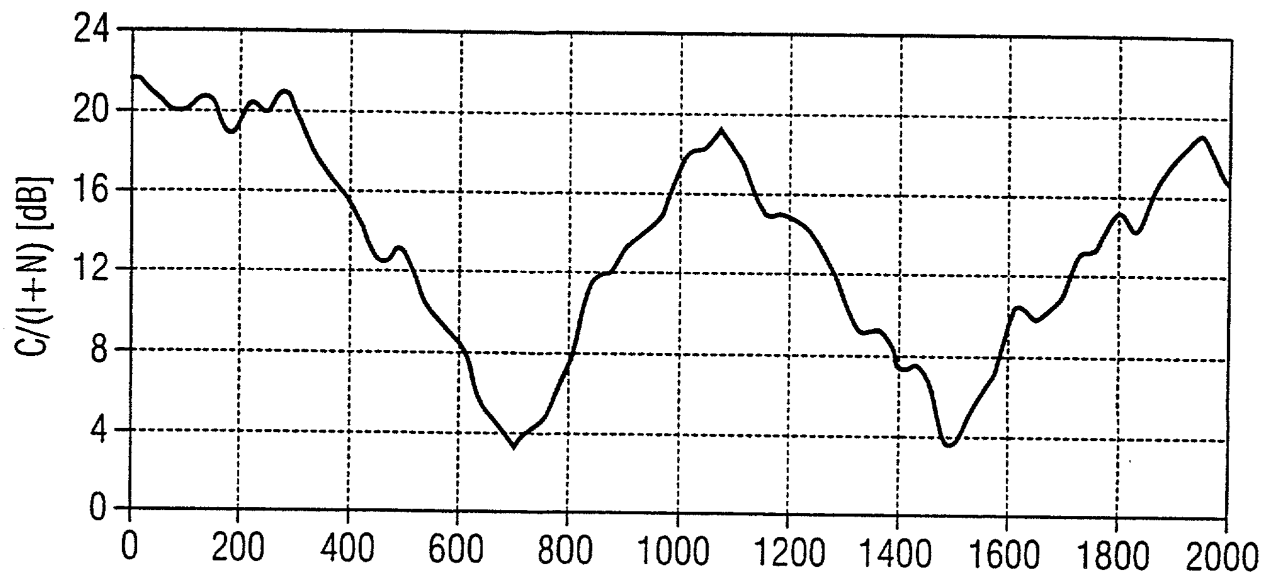
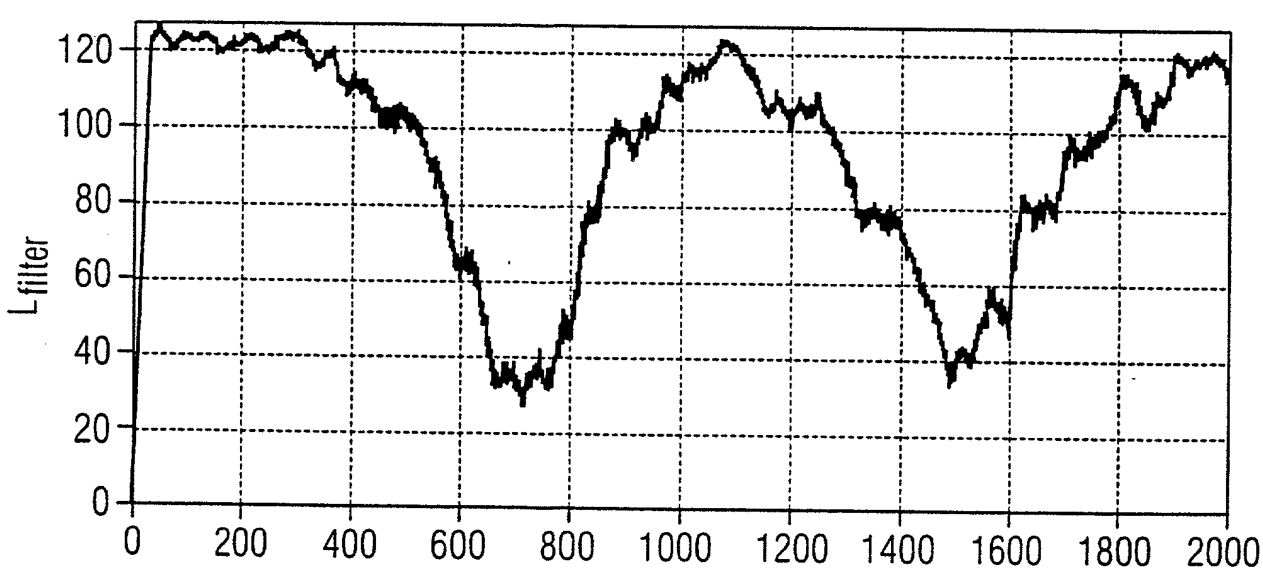

24
20
16
12
8
4
0
C/(I+N) [dB]
0
200
400
600
800
1000
1200
1400
1600
1800
2000

FIG 4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100
80
60
40
20
0
L filter
0
200
400
600
800
1000
1200
1400
1600
1800
2000

FIG 5

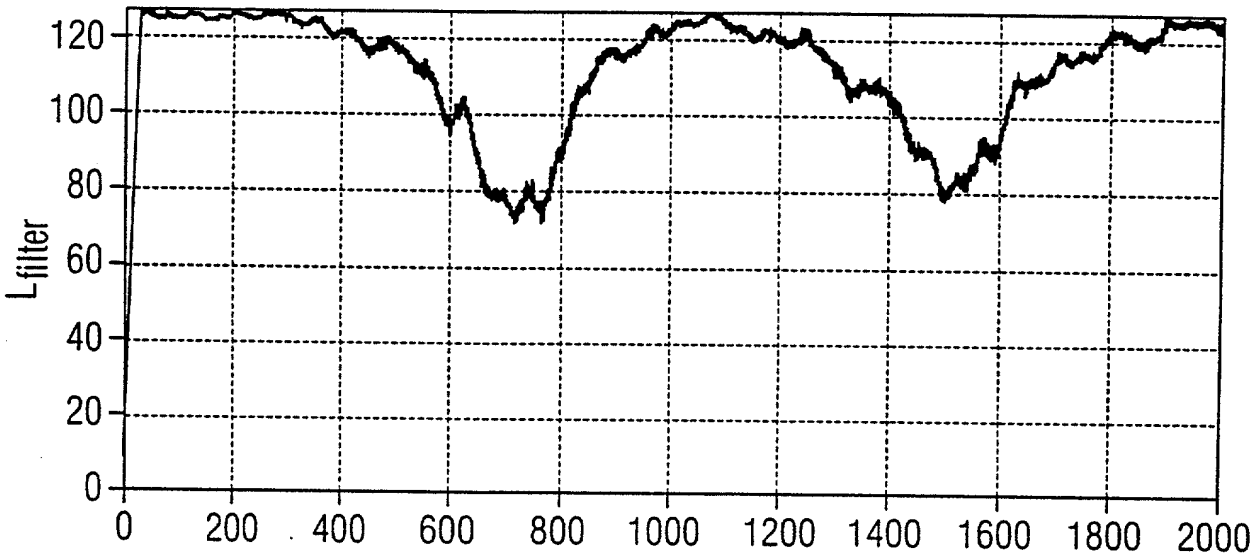


FIG 7

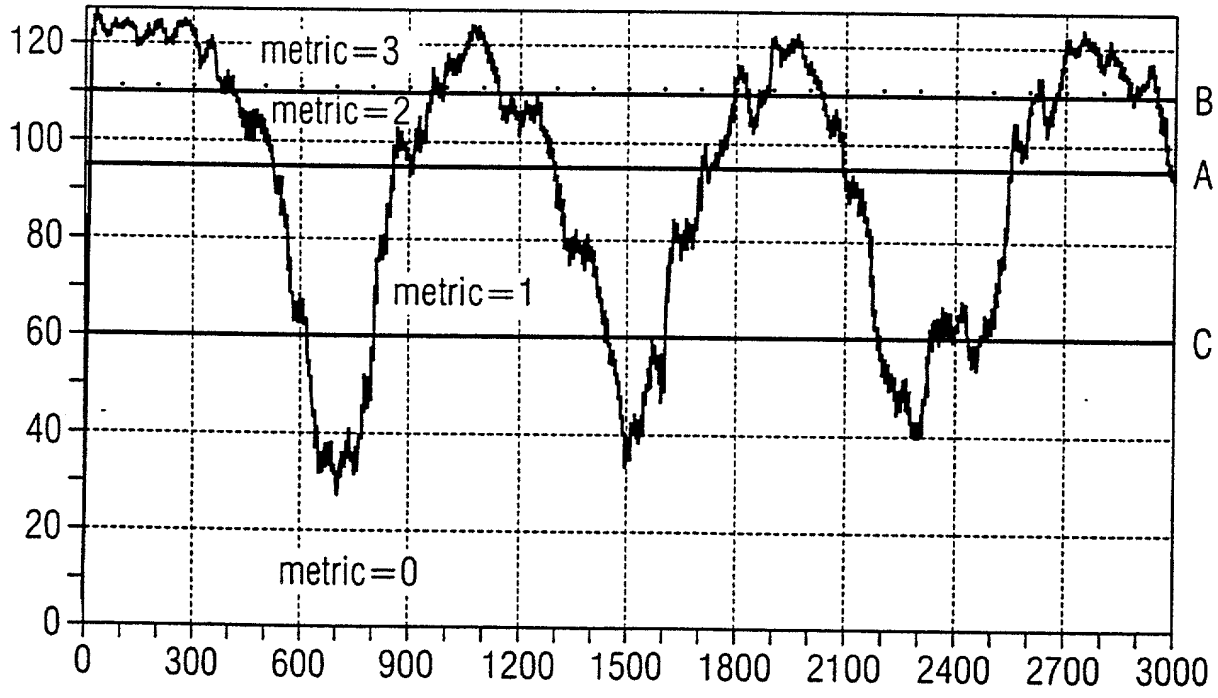


FIG 6A

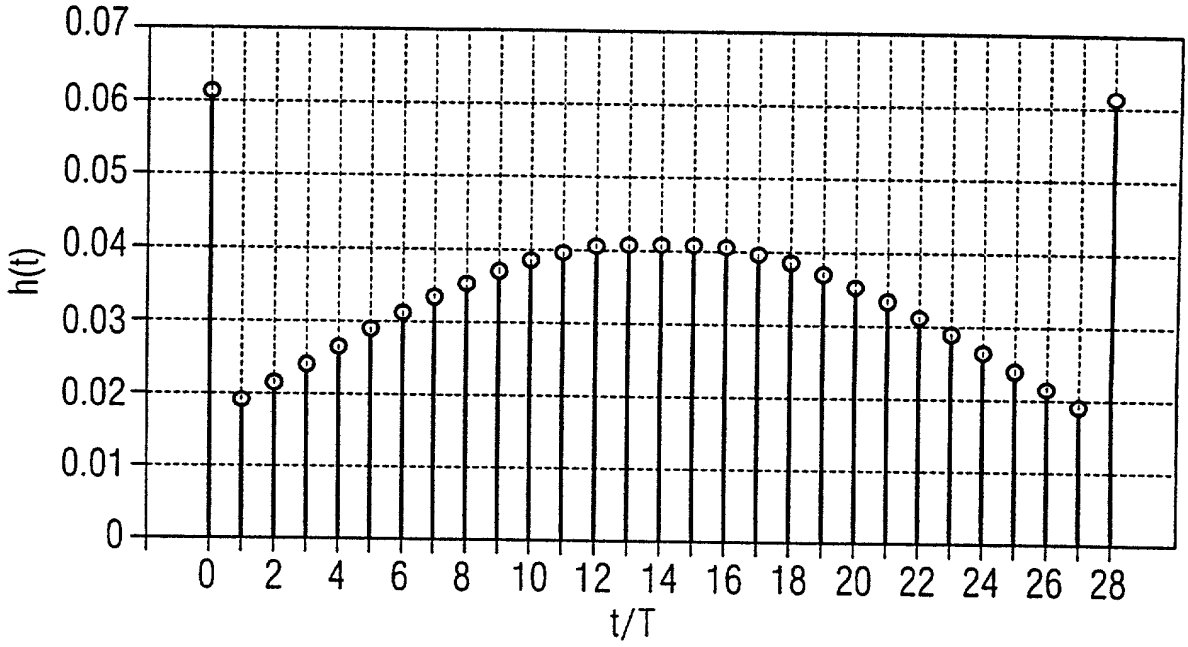
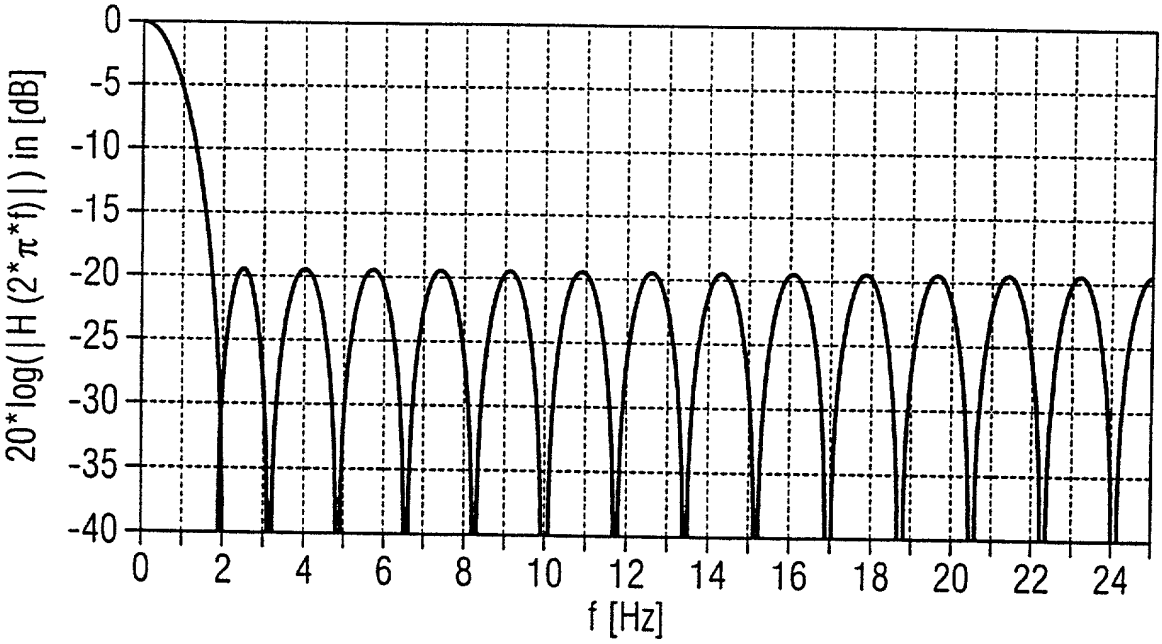


FIG 6B



COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY
(Includes Reference to PCT International Applications) PCT/DE99/02737

ATTORNEY'S DOCKET NUMBER
112740-155

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name, I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD AND APPARATUS FOR ESTIMATING THE TRANSMISSION QUALITY OF A DIGITAL COMMUNICATION SIGNAL

the specification of which (check only one item below):

☐ is attached hereto.

☒ was filed as United States application
Serial No. 09/787,960

on March 22, 2001.

and was amended

on _____(if applicable).

☐ was filed as PCT international application

Number _____

on _____.

and was amended under PCT Article 19

on _____(if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. 119:

COUNTRY (if PCT indicate "PCT")	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 USC 119
Germany	198 43 468.5	22 September 1998	☒ YES ☐ NO
			☐ YES ☐ NO
			☐ YES ☐ NO
			☐ YES ☐ NO
			☐ YES ☐ NO

Combined Declaration For Patent Application and Power of Attorney (Continued) (Includes Reference to PCT International Applications), PCT/DE99/02737

ATTORNEY'S DOCKET NO. 112740-155

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject mater of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, Untied States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

PRIOR U.S. APPLICATIONS OR PCT INTERNATIONAL APPLICATIONS DESIGNATING THE U.S. FOR BENEFIT UNDER 35 U.S.C. 120:

U.S. APPLICATIONS		STATUS (Check one)		
U.S. APPLICATION NUMBER	U.S. FILING DATE	PATENTED	PENDING	ABANDONED

PCT APPLICATIONS DESIGNATING THE U.S.					
PCT APPLICATION NO	PCT FILING DATE	U.S. SERIAL NUMBERS ASSIGNED (if any)			

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

SIGNATURE OF INVENTOR 201	SIGNATURE OF INVENTOR 202	SIGNATURE OF INVENTOR 203
DATE: 13.06.2001	DATE: 13.06.2001	DATE: 29.06.01